# Remote Sensing and Vegetation Study

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## Abstract

Remote Sensing, with its unique characteristics of multi-spatial, multi-temporal, and multi-spectral resolutions, provides a tool to conduct vegetation study. Remotely sensed data are available in spatial resolution from less than one meter to over a kilometer. The revisit time for a certain study area can be from one day to around one month. Satellite imagery provides information from visible wavelength region to near infrared, middle infrared, thermal infrared, and microwave wavelength regions. Remotely sensed data, as one important data source and with low cost comparing with in-situ measurement, have been used on urban planning, yield prediction, hazard estimation, land use land cover classification, global climate change, and many more. In this paper, two examples of using remotely sensed data to capture information of vegetation from large scale to small scale will be briefly described.

## Introduction

Remote Sensing, with its unique characteristics of multi-spatial, multi-temporal, and multi-spectral resolutions, provides a tool to conduct vegetation study. Most popularly used remote sensing data sources include the Advanced Very High Resolution Radiometer (AVHRR), Moderate Resolution Imaging Spectroradiometer (MODIS), Landsat Multispectral Scanner (MSS), Landsat Thematic Mapper (TM), Landsat Enhanced Thematic Mapper Plus (ETM+), SPOT High Resolution Visible (HRV), IKONOS, Quick Bird, and RADARSAT. These sensors' spatial, spectral, and temporal resolutions vary individually and are listed in table 1.

Lower spatial resolution imagery from AVHRR and MODIS has the advantage of studying global vegetation distribution and change, as well as climate change. Imagery with moderate spatial resolution such as Landsat and SPOT have been extensively used on regional to local vegetation study, including land use land cover classification, crop yield prediction, drought mapping, biophysical features characterization, and many more. While higher spatial resolution imagery from IKONOS and Quick Bird is idea for urban planning and precision agriculture. Radar imagery has been used for moisture mapping and digital elevation model derivation. Its broad usage is also because of its special features of full function in any weather conditions and the penetration ability.

Table 1. Examples of Satellite Sensors for Vegetation Study.

| Sensors | Spatial Resolution (m) | Temporal Resolution (day) | Spectral Resolution |
|---|---|---|---|
| AVHRR | 1000 x 1000 | 1 | 5 bands in Visible, Near-Infrared, Thermal |
| MODIS | 250 x 250; 500 x 500; 1000 x 1000 | 1 | 36 bands in Visible, Near-Infrared, Thermal |
| Landsat MSS | 79 x 79 | 18 | 4 bands in Visible, Near-Infrared |
| Landsat TM | 30 x 30;<br>120 x 120 (thermal band) | 16 | 7 bands in Visible, Near-Infrared, Thermal |
| Landsat ETM+ | 30 x 30; 60 x 60 (thermal band); 15 x 15 (pan) | 16 | 8 bands in Visible, Near-Infrared, Thermal, Panchromatic |
| SPOT HRV | 20 x 20; 10 x 10 (pan) | 26 | 4 bands in Visible, Near-Infrared, Panchromatic |
| IKONOS | 4 x 4; 1 x 1 (pan) | <3 | 5 bands in Visible, Near-Infrared, Panchromatic |
| Quick Bird | 2.44 x 2.44;<br>0.64 x 0.64 (pan) | <3 | 5 bands in Visible, Near-Infrared, Panchromatic |
| RADARSAT | 28 x 25; 28 x 35; 10 x 9; 20 x 28; 50 x 50; 100 x 100 | 24 | 1 band in Microwave |

**Linkage between Remote Sensing and Vegetation Study**

One important index derived from remotely sensed data is the Normalized Difference Vegetation Index (NDVI) in early 1970s (Reed *et al*. 1994). NDVI is the ratio of the reflectance difference of Near-Infrared and Red bands to the sum of these two variables. This index represents the greenness of vegetation in a certain condition. The higher NDVI value is, the more vigorous of vegetation is. Because NDVI is a ratio, it reduces the effects from soil and background in a certain level. Besides this, the advantages of using NDVI also include reducing data dimensions, standardizing comparisons, and enhancing the vegetation signal. Vegetation's annual phonological cycle can be explained by mapping annual NDVI changes in annual basis (Figure 1).

Twelve metrics can be derived from figure 1 in three categories: time (onset of greenness, time of maximum NDVI, end of greenness, and duration), value (NDVI of onset of greenness, maximum NDVI, NDVI of end of greenness, and range of NDVI) and derived measurements (accumulated NDVI, rate of green up, rate of senescent, and modality) (Reed *et al*. 1994). Obviously, seasonal characteristics of plants are closely related to characteristics of annual cycle of weather pattern; therefore, changes in plant phenological events may signal important year-to-year climatic variations or even global environmental change. Monitoring ecosystems that are sensitive to climate change can improve our understanding of the relationships between climate and ecosystem dynamics. This improved understanding is critical for future land use planning purpose. Seasonal characteristics of plants are closely related to characteristics of annual cycle of weather pattern, therefore, changes in plant phenological events may signal important year-to-year climatic variations or even global environmental change.

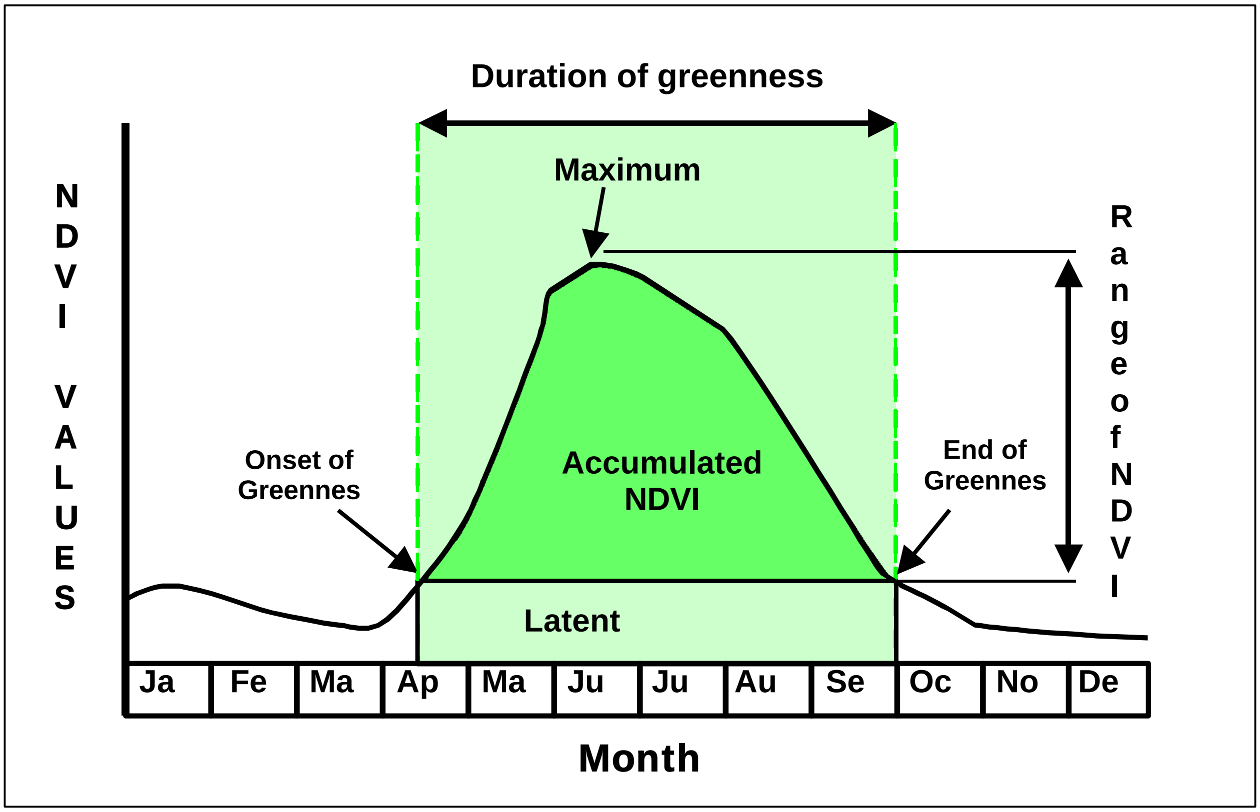


**Figure 1.** Vegetation phonological metrics (Reed *et al*. 1994).

**Large-Scale Study: Spectral Variation of Different Ecoregions over Six Years in the Mixed Prairie Ecosystem**

Ecosystems play an important role in the exchange of water, energy, and greenhouse gases between the soil, vegetation, and the atmosphere. Researchers have been focusing on large-scale changes in terrestrial ecosystems (*e.g.*, Dixon *et al*. 1994, Ojima *et al*. 1994, Lambin and Ehrlich 1997). It is accepted that at the global scale rapid environmental changes are mainly a result of climatic variations and anthropogenic activities. Environmental degradation is also associated with declines in primary productivity that alter biogeochemical exchanges between the earth and atmosphere (Running *et al*. 1994). Monitoring ecosystems that are sensitive to climate change can improve our understanding of the relationships between climate and ecosystem dynamics. This improved understanding is critical for future land use planning purpose.

Saskatchewan bounded from $49^0$N to $60^0$N latitude and from $101.5^0$ to $110^0$ W longitude (Figure 2) with gradient climate, diverse ecoregions, and intensive human activities (in the southern part of the province) (Fung 1999); which are advantageous to studying global climate change. The NDVI values derived from data captured from AVHRR were plotted along time series for each ecoregion, Cypress Upland, Mixed Grassland, Moist Mixed Grassland, and Aspen Parkland (Figure 3). The graph showed that the maximum NDVI values changed from one year to another.

The lowest maximum NDVI values were found in 1993 and 1995 and the highest maximum NDVI value occurred in 1996. Among these four ecoregions, Mixed Grassland had the lowest maximum NDVI values throughout these six years, and it greened up later and senesced earlier than other ecoregions in the prairie ecosystem. From geographic perspective, Cypress Upland is at the same latitude with Mixed Grassland but is at a higher elevation, so the vegetation type is more closely related to the Moist Mixed Grassland, which is northward of the Mixed Grassland. The NDVI curves for these two ecoregions were close to each other. Aspen Parkland is located in the northern part of this region, and is mixed with grasses and trees. The spectral near-infrared reflectance of trees is higher than it is from grasses. NDVI is the difference between reflectance of near-infrared and red wavelengths over the sum of these two values; therefore, it was not surprising that the NDVI values for Aspen Parkland were the highest (Guo 2001a).

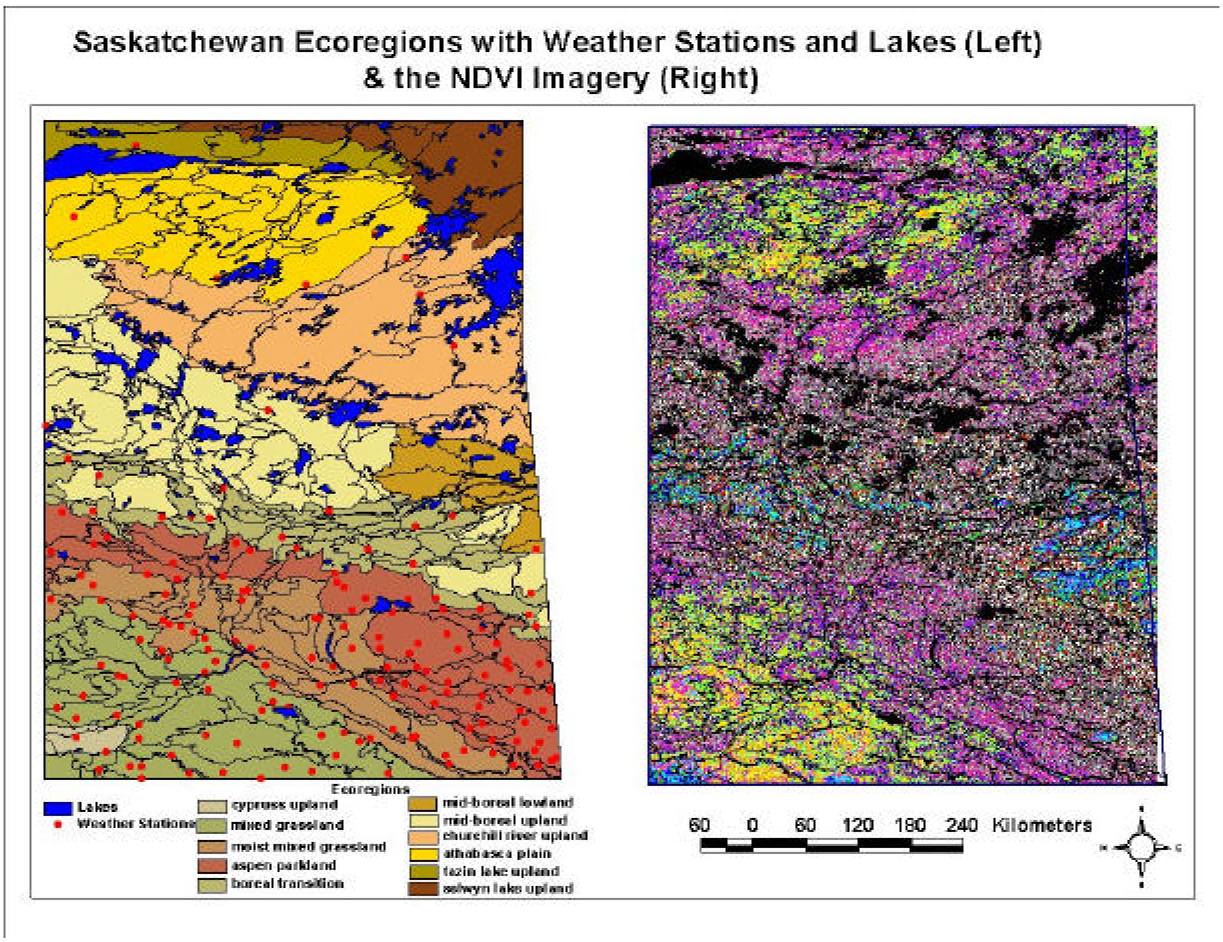


**Figure 2.** Saskatchewan, Canada. The left graph shows ecoregions, weather stations, and lakes. The right graph shows the pseudo color NDVI imagery from July 21, 1998.

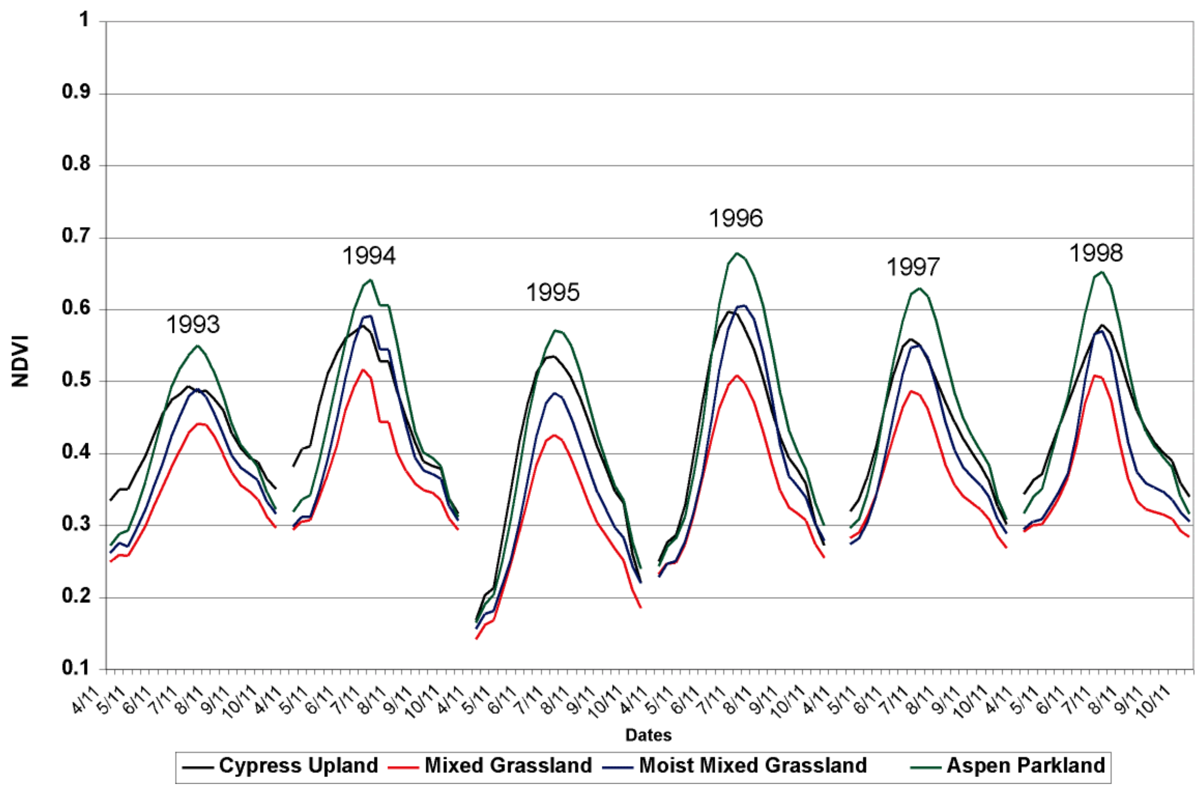


**Figure 3**. NDVI values of four ecoregions in prairie ecosystem for each growing season from 1993 to 1998.

## Small-Scale Study: Discrimination of Different Grassland Management Practices in a Tallgrass Prairie Ecosystem

Prairies of the Central U.S. have been highly fragmented by conversion of these lands to cropland and non-native grasslands. It is estimated that only 1% of all native prairies still exist in the plains of North America. Prairie species composition and biological function are differentially altered by fragmentation and various land use practices. Examples of prairie land use practices include, grazing by livestock, haying, burning, and re-vegetation activities. The alteration of prairie biophysical properties also influences surface hydrology, plant and animal diversity, biogeochemical fluxes, as well as future land use practices. Although the biological and ecological responses of prairies to fragmentation and land use continue to be investigated, there remains much unknown about the impacts of changing land use practices on the present agro-ecosystems of the U.S. Central Great Plains. There is particular paucity in our understanding of land use impacts at the landscape and ecosystem scales. This is because most ecological models simulate larger-scale processes (*i.e.*, field level). For these reasons, part of our NASA EPSCoR project focused on the use various remote sensors for spectrally discriminating among grassland types in Douglas County, Kansas which is geographically located in a tallgrass agro-ecosystem in the Central U.S. One component of the study evaluated the use of multi-date Landsat TM satellite imagery for discriminating among six grassland types (three different grassland management practices - haying, grazing, Conservation Reserve Program (CRP) - for both cool and warm season grasslands) (Price *et al*. 1999a). This research documented that grassland management practices significantly influence the biophysical characteristics of the site and that mid-summer is the best time to spectrally separate the six grassland types (Guo *et al*. 2000a; Guo *et al*. 2000b; Guo and Price 2001b). Optimal spectral variables and vegetation indices could be identified to classify grassland management practices (Price *et al*., 1999b). We also learned that the combination of multi-date Synthetic Aperture Radar (SAR) data with Landsat TM did not improve discrimination among the six types. We did learn, however, that use of SAR data can improve discrimination of pasture lands (lands being grazed by livestock) from the other two grassland management types (Price *et al*. in press).

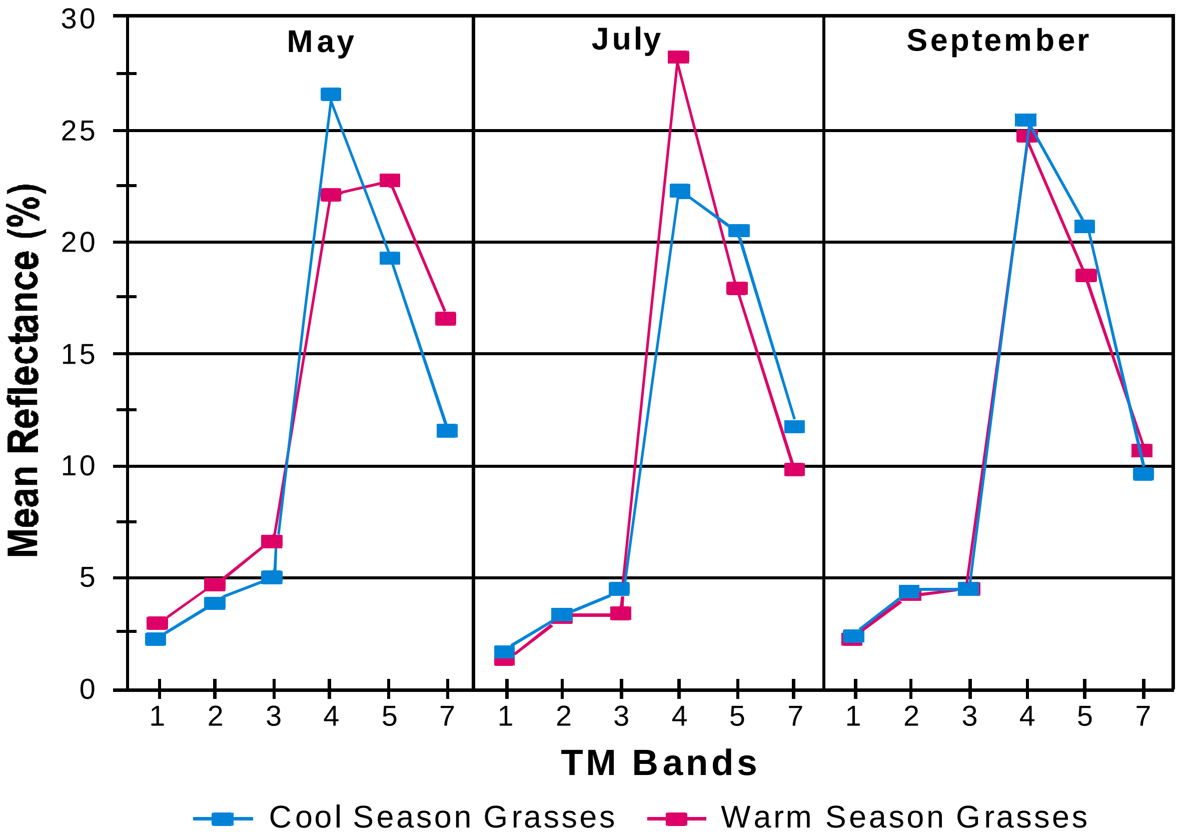


**Figure 4.** Spectral response curves for the three TM image acquisition dates, the six TM bands, and the cool and warm season grassland types within the study area. The higher reflectance values in May for band 4 (NIR) and low values in bands 5 and 7 (MIR bands) for the cool season grasses are indicative of higher concentrations of photosynthetically active vegetation. In July, the opposite is true with the warm season grasses now showing higher photosynthetic activity. Lower reflectance values in bands 5 and 7 are indicative of greater water absorption which suggests higher levels of plant moisture in the cool season grasses in May, and higher moisture content in the warm season plants in July. In September, the cool and warm season sites have similar reflectance patterns.

Figure 4 is an example showing the spectral response curves for the three TM image acquisition dates, the six TM bands, and the cool and warm season grassland types within the study area. The higher reflectance values in May for band 4 (NIR) and low values in bands 5 and 7 (MIR bands) for the cool season grasses are indicative of higher concentrations of photosynthetically active vegetation. In July, the opposite is true with the warm season grasses now showing higher photosynthetic activity. Lower reflectance values in bands 5 and 7 are indicative of greater water absorption which suggests higher levels of plant moisture in the cool season grasses in May, and higher moisture content in the warm season plants in July. In September, the cool and warm season sites have similar reflectance patterns because the image was acquired too early to catch the cool and warm season grasslands differences (Guo and Price 2001a).

## Summary

In summary, remote sensing is an effective tool for vegetation study. The application can be ranged from large scale studies such as climate change and biogeochemical cycle to small scale studies such as precision agriculture. However, remote sensing has its limitations. It is only one data source and the accuracy depends on many factors including sensors and data handling and processing procedures. One important component to use remotely sensed data is to calibrating these data with ground truth information.

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